B.E.A.S.T.

[Backpackable-Easily-Assembled-Sustainable-Turbine]

System Design and Project Plan

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12 October 2010

Sean Smith

- ***Mechanical Engineer***
- ***Project Manager***

Joshua Gibb

- ***Mechanical Engineer***

Moses Rotich

- ***Electrical Engineer***

Yixiao Zhang

- ***Electrical Engineer***

Table of Contents

Background

Many of us are dependent upon our small electronics ranging from cell phones to laptops for functions varying from information gathering to long distance communication. Unfortunately all of these devices are dependent upon electricity in the form of rechargeable batteries which only last for a set period of usage time and then depend on a steady source of electricity for recharging. On extended stays in areas which do not offer an electricity source, an environmentally-friendly, sustainable, and easily implemented power source is needed.

The BEAST will be a solution to that problem intended specifically for long-term trips into remote areas and visits to developing nations where a base camp is required. Military applications and disaster relief efforts are also key markets. The device will consist of a wind turbine that can fit within or on a hikerȇs backpack at a reasonable weight, be easily assembled in the field with little technical prowess, and supply enough power to efficiently charge cell phone and laptop batteries.

System Overview

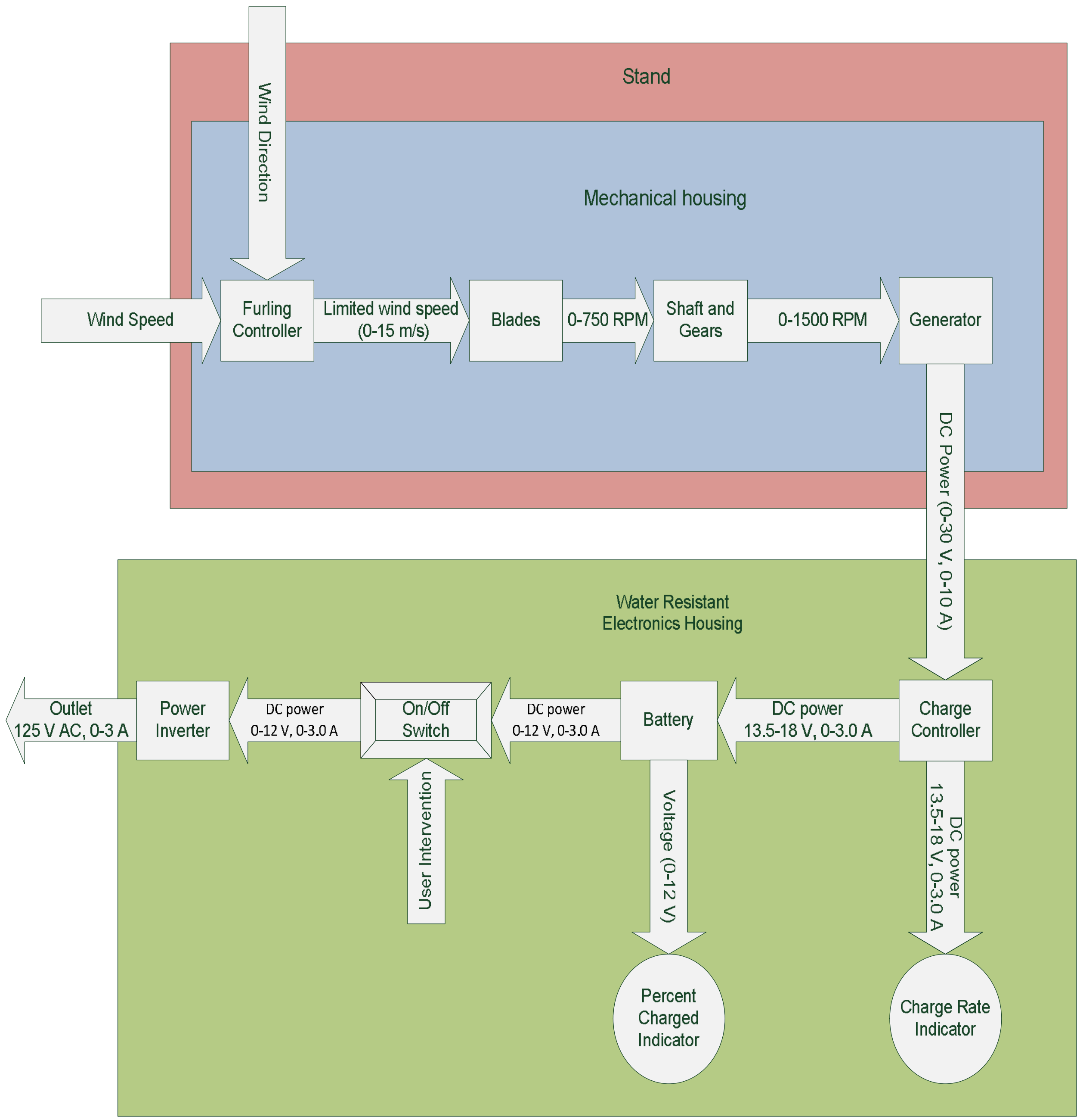
The finished wind turbine will deliver electricity to a NEMA Type B outlet (standard in U.S. homes) by converting wind energy into mechanical rotational energy and then converting that mechanical energy into electrical energy. The wind energy will be captured by blades that are attached to a hub that is free to rotate. The hub will be elevated on a stand such that the lowest point that the blades spin will be at least 2.14m above the ground. The rotation of the hub will turn the shaft of an electricity generator and thus convert wind energy into electricity. The produced electricity will then be stored in a battery and the battery will supply electricity to an outlet via an inverter. An indicator will tell the user how much power is being produced instantaneously and how much power is available in the battery. The battery pack will also be removable for transportation or use away from the turbine.

For the wind turbine to be used the blades must be attached to the hub and the hub must be attached to the top of a collapsible stand. The stand will have sections that are approximately 1m in length and when fastened together achieve a height of at least 2.63m. Each section will have attachment points for tethers that can be attached to the surroundings for stability. The wind turbine and all of its components will be able to be collapsed into a space no greater than 85 liters and weigh no more than 23 kg.

During high winds the furling mechanism of the wind turbine will automatically turn it out of the wind so that over-speed of the generator does not occur. Since it may be desirable to disassemble the wind turbine when the wind is blowing it is recommended that a stick or provided tool be used to manually turn the turbine out of the wind to aerodynamically brake the unit.

The turbine will be a complete assembly of the turbine, blades, stand, tethers, battery pack and circuitry.

System Block Diagram



Functional Description of Blocks

Stand: Raises the wind-turbine up to more productive winds and keeps the lowest blades at least 2.14 meters off of the ground. The stand provides support in winds up to 20 m/s.

Mechanical Housing: The mechanical housing will protect the user from moving parts such as gears, while protecting those moving parts from the environment. It will rotate atop the stand according to the wind direction.

Furling Controller: Limits the effective wind speed acting on the blades by turning the blades out of the wind up to 90°. This mechanical controller acts as protection against large wind force and keeps the turbine operating at a safe speed.

Inputs: Wind speed (0-20 m/s) and direction

Outputs: Effective wind speed from 0-15 m/s

Blades: Mounted on the input shaft, the blades convert the effective wind speed into a usable torque.

Inputs: Effective wind speed from 0-15 m/s

Outputs: 0-750 RPM

Gearing: Increases the initial RPM provided by the blades to an RPM suitable for power generation at a ratio of 2:1.

Inputs: 0-750 RPM

Outputs: 0-1500 RPM

Generator: A permanent-magnet DC generator which converts the mechanical energy of the blades into electrical energy.

Inputs: 0-1500 RPM

Outputs: DC power (0-30V, 0-10 A)

Water Resistant Electronics Housing: Provides water resistance to the electronic circuitry.

Charge Controller: Converts and regulates the power coming from the generator into a proper power for charging the battery. It also prevents charge backflow and calculates the battery charging rate.

Inputs: DC power (0-30 V, 0-10 A)

Outputs: DC power (13.5-18 V, 0-3.0 A)

Charge Rate Indicator: Displays the rate, in watts, at which the charge controller is charging the battery.

Inputs: DC power (13.5-18 V, 0-3.0 A)

Outputs: Visualization of the charge rate in watts

Battery: A battery which stores at least 200 Wh of energy.

Inputs: DC power (13.5-18 V, 0-3.0 A)

Outputs: DC power (12 V, 0-18 A)

Percent Charged Indicator: Indicates the percent charge available in the battery.

Inputs: Voltage (0-12 V)

Outputs: Visualization of the percent charge available in the battery

On/Off Switch: Determines if the energy available in the battery is to be converted to AC.

Inputs: DC power (0-12 V, 0-3.0 A) and human intervention

Outputs: If the switch is on then 12 V DC will be allowed through, otherwise no current will be allowed past this point.

Power Inverter: Converts the DC into a usable 125 V AC which is supplied to the user via a standard outlet.

Inputs: DC power (12 V, 0-18 A)

Outputs: AC power (125 V AC, 0-3 A)

Organization and Management

Sean Smith (Mechanical Engineer)

Sean is the project manager and is responsible for ensuring that all of the team members communicate and that the project is completed on time and within budget. Parts ordering and any major design changes must be approved by Sean to ensure that the final product meets the requirement specifications. He is in charge of the generator selection and gearing. He will work in conjunction with Josh on the furling mechanism and blades and acts as the secondary engineering for any component on which Josh is the primary engineer.

Joshua Gibb (Mechanical Engineer)

Josh will be responsible for CAD drawings and simulation of the wind turbine. He will be in charge of designing and building the housing and stand. He will work in conjunction with Sean on the furling mechanism and blades and with Moses on the electronics housing. Due to his practical knowledge, he will be the lead integration engineer. He is the secondary engineering for any component on which Sean is the primary engineer.

Moses Rotich (Electrical Engineer)

Moses is responsible for the PCB design for the charge controller and selection of the inverter. He will work with Josh on the electronics housing and with Yixiao on the construction and design of any other electrical components of the system. He is the secondary engineer for any component on which Yixiao is the primary engineer.

Yixiao Zhang (Electrical Engineer)

Yixiao is responsible for the MULTISIM schematic of the charge controller, the user interface design and construction, and battery selection. She will work with Moses on the design and construction of any other electrical system components as well. She is the secondary engineer for any component on which Moses is the primary engineer.

All team members will be responsible for contributing equally to all documentation. Every member is expected to come prepared to contribute to every meeting. Even though each member is assigned specific tasks, it is important to note that all engineers ought to be familiar with each otherôs system with the integrated unit as a whole in mind.

Estimated Costs

Description	Part Number/ Specifics	Height/OD (in)	Width/ID (in)	Thickness (in)	Length (ft)	Price	Location	Quantity	Total
Battery	SLA battery (12V 18Ah)					$40.00	Amazon.com	1	$40.00
Bearing, DS, F	6384k344		0.375			$5.62	McMaster-Carr	2	$11.24
Blades	Set of three injection molded	46 in rotor diameter					http://www.defender.com	1	$125.00
Charge Controller	12V Voltage Regulator, Capacitor, Resistors						Lab room		
DC-AC inverter	DC to AC Power Inverter					$26.00	Amazon.com	1	$26.00
Electrical cable	GB 46-315 Electrical Cable Ties				1.17	$15.00	Amazon.com	1	$15.00
Electrical outlet	Receptacle(with cover)					$16.00	Amazon.com	1	$16.00
Gears	Steel Spur Gear					$9.80	SDP-SI.com	2	$19.60
Generator	443540 PM DC Generator					$149.00	windsteam power.com	1	$149.00
Housing Material	6061 Aluminum Sheet	24	24	0.125		$48.08	McMaster-Carr	1	$48.08
Hub Material	6060 Aluminum Sheet	12	12	0.125		$26.29	McMaster-Carr	1	$26.29
Indicator	Electricity Power Monitor					$26.00	Amazon.com	1	$26.00
LED indicator	LED Encasement					$4.00	Lab room	2	$8.00
Paracord for stand ties					100	$3.65	campingsurvival.com	2	$7.30
Professional Circuit Board	Circuit Board	2.5	3.8			$51.00	expresspcb.com	1	$51.00
Rectifier	Rectifier Diode					$0.98	Amazon.com	6	$5.88
Shaft Material	12 O1 Steel	0.25				$16.38	McMaster-Carr	1	$16.38
Tube, Square		1.5	1.5	0.125	4	$20.40	metalsdepot.com	1	$20.40
Tube, Square		1.75	1.75	0.125	4	$25.52	metalsdepot.com	1	$25.52
Tube, Square		2	2	0.125	4	$29.44	metalsdepot.com	1	$29.44

Total Available Funds	$1,000
Current Total Expenses	$666.13
Funding Left	$333.87

DS = Double Sealed

OD = Outside Diameter

F = Flanged

ID = Inside Diameter

Work Breakdown Structure

Fall 2010

ID	Task	Description	Deliverables	Start/Stop	People*
F1.00	Project Management	Ensure that the team is on schedule and under budget	Constraints and specifications met	Aug 23-Dec 10	S
F2.00	Documentation	Keep records of all design work, research and tests	Documents. Engineering Notebooks	Aug 23-Dec 10	S, J,M,Y
F3.00	Project Selection	Make a final choice of which project to pursue	Verbal confirmation with professors	Aug 23-Sept 7	S,J,M,Y
F4.00	Project Specification	Technical description of the project's goals	Document	Sept 8 -Sept 28	S,J,M,Y
F5.00	System Design Report	Technical Description of the systems operation, project plan, and budget	Document	Sept 29-Oct 12	S,J,M,Y
F6.00	System Design and Project Plan Formal Presentation	Technical Description of the systems operation, project plan, and budget	Presentation	Oct 14	S,J,M,Y
F7.00	**Component Design**	Design the subcomponents	Detailed design of subcomponents	Sept 29-Nov 30	S,J,M,Y
F7.10	**Mechanical Design**	Design of Mechanical Systems	Detailed design of mechanical components	Sept 29-Nov 30	S,J
F7.11	*Generator Selection*	Select a suitable generator for wind generation	Product number, reasoning, specifications	Sept 29-Oct 12	S
F7.12	*Blade Design*	Design or find blades suitable for the generator	Detailed design, CAD drawing	Oct 13-Nov 2	S,J
F7.13	*Gear Design*	Design a gearing system to bring increase the RPM's to the rated RPM of the generator	Detailed design, CAD drawing	Nov 3-Nov 16	S
F7.14	*Housing Design*	Design a housing for the gears and generator to sit atop the stand	Detailed design, CAD drawing	Nov 17-Nov 30	J
F7.15	*Furling Design*	Design a mechanical controller to limit the maximum wind speed of generation	Detailed design, CAD drawing	Oct 13-Nov 16	S,J
F7.16	*Stand Design*	Design a stand which will raise the wind-turbine up to better winds and keep the lowest blades from passing within 2.14 meters of the ground	Detailed design, CAD drawing	Nov 3-Nov 30	J

*S-Sean, J-Josh, M-Moses, Y-Yixiao

F7.20	**Electrical System Design**	Design the electrical system which stores and supplies the generated power to the user	Detailed design of electrical system components	Sept 29-Nov 23	M,Y,J*
F7.21	*Battery Selection*	Select a light-wieght, durable battery capable of storing 200 Wh of energy	Detailed design, product number and specifications	Sept 29-Oct 12	Y
F7.22	*Charge Controller*	Regulates and converts the generated power into power suitable for charging the battery	Detailed design, schematics	Sept 29-Oct 26	M,Y
F7.23	*Power Inverter*	Converts the DC power in the battery into 125 V AC for the user	Detailed design, schematics	Sept 29-Oct 19	M
F7.24	*User Interface*	Outlet, On/Off Switch, Charge Rate Indicator, Charge Amount Indicator	Detailed design, schematics	Oct 27-Nov 9	Y
F7.25	*Electronics Housing*	Design a box to protect the electronic components from weather	Detailed design, CAD drawing	Nov 10-Nov 23	M,J
F8.00	Final Design Report	Final system and subsystem design	Document	Nov 9-Dec 7	S,J,M,Y
F9.00	Final Design Formal Presentation	Presentation of final design	Presentation	Dec 10	S,J,M,Y

*S-Sean, J-Josh, M-Moses, Y-Yixiao

Work Breakdown Structure

Spring 2010

ID	Task	Description	Deliverables	Start/Stop	People*
S1.00	Project Management	Ensure that the team is on schedule and under budget	Constraints and specifications met	Jan 18-May 8	S
S2.00	Documentation	Keep records of all design work, research and tests	Documents. Engineering Notebooks	Jan 18-May 8	S,J,M,Y
S3.00	**Parts Assembly/Testing**	Assembling of components	Working components/meet specifications documented	Jan 18- Mar 11	S,J,M,Y
S3.10	**Mechanical Systems**	Assembly of mechanical components	Working components/meet specifications documented	Jan 18- Mar 11	S,J
S3.11	*Generator Testing*	Test the generator's output for given RPM's	Working components/meet specifications documented	Jan 18-Jan 31	S
S3.12	*Gear and Shaft*	Assemble the gears and shaft and test the ratio	Working components/meet specifications documented	Jan 18-Feb 7	S
S3.13	*Mechanical Housing*	Construct the housing for the gears and generator	Working components/meet specifications documented	Feb 8-Feb 21	J
S3.14	*Blade Mounting*	Construct the blade mount and mount the blades	Working components/meet specifications documented	Feb 8-Feb 21	S,J
S3.15	*Furling*	Construct the mechanical controller	Working components/meet specifications documented	Feb 12-Mar 11	S,J
S3.16	*Stand*	Construct the stand	Working component/meets specifications	Feb 12-Mar 11	J
S3.20	**Electrical Systems**	Assemble the electrical components	Working components/meet specifications documented	Jan 18- Mar 11	M,Y,J
S3.21	*Charge Controller*	Construct and ensure that the charge controller outputs steady DC	Working components/meet specifications documented	Jan 18-Feb 21	M,Y

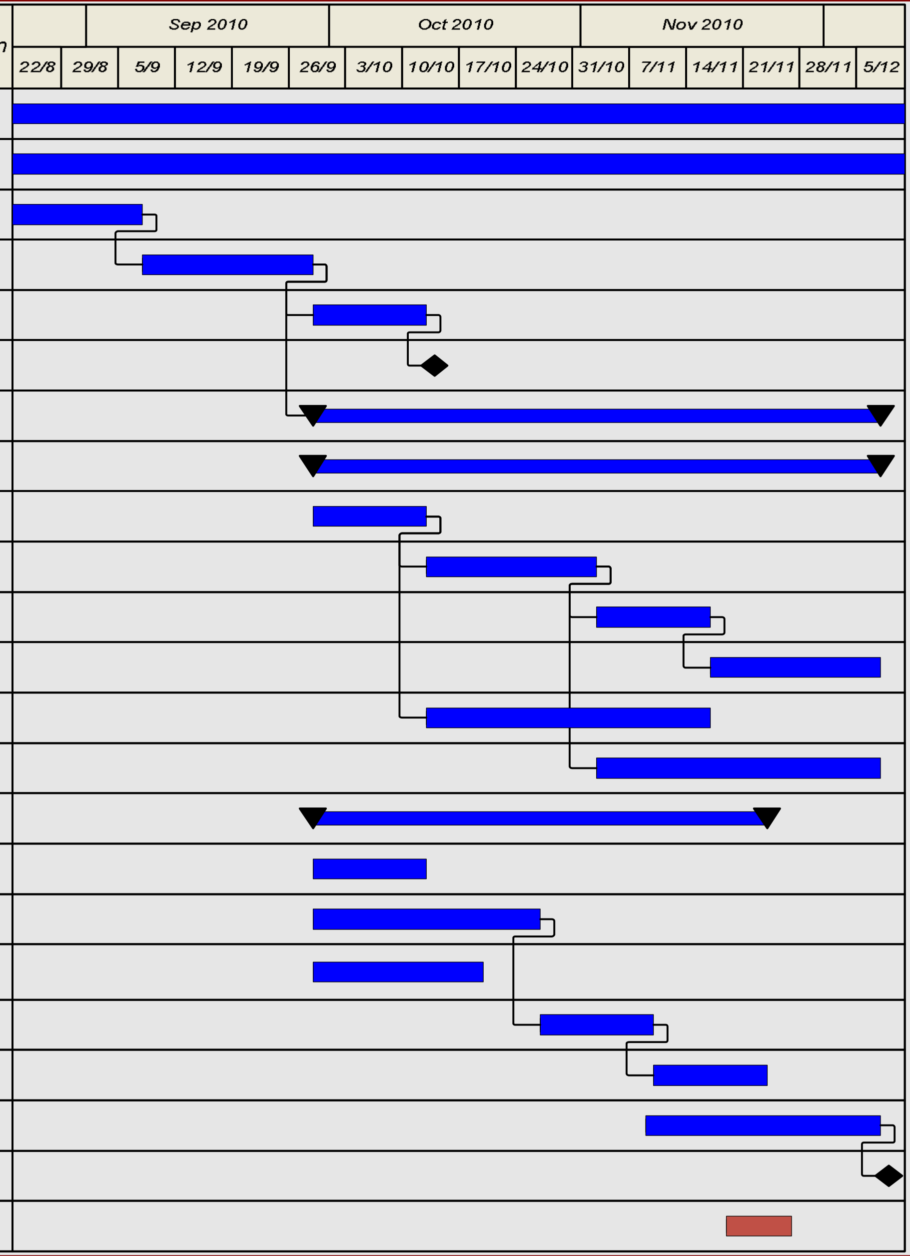
*S-Sean, J-Josh, M-Moses, Y-Yixiao

S3.22	*Power Inverter*	Construct and test the conversion from 12 V DC to 125 V AC	Working components/meet specifications documented	Jan 18-Feb 7	M*
S3.23	*User Interface*	Test the indicators, switches, and outlet	Working components/meet specifications documented	Feb 8-Feb 28	Y
S3.24	*Battery Testing*	Perform a runtime test on the battery to ensure capacity	Working components/meet specifications documented	Feb 14-Feb 28	Y
S3.25	*Encasement*	Construct weather resistant encasement and test	Working components/meet specifications documented	Mar 1-Mar 11	M,J
S4.00	Project Status Report Formal Presentation	Present the status of the project	Presentation	Mar 10	S,J,M,Y
S5.00	System Integration	Combine the components	Complete system	Mar 14-Apr 10	S,J,M,Y
S6.00	System Testing and Modification	Test system for technical specifications; modify as needed	Fully functioning prototype	Apr 11-Apr 28	S,J,M,Y
S7.00	Acceptance Tests Complete	Prove that the device meets specifications	Monitored testing	Apr 28	S,J,M,Y
S8.00	User's Manual	Describes how to use the device along with any special considerations	Document	Apr 20-May 3	S,J,M,Y
S9.00	Final Report	Final report on the prototype	Document	Apr 13-May 3	S,J,M,Y
S10.00	Final Project Formal Presentation	Presentation about the prototype	Presentation	5-May	S,J,M,Y
S11.00	Engineering Showcase	Combined presentation of prototypes	Presentation	8-May	S,J,M,Y

*S-Sean, J-Josh, M-Moses, Y-Yixiao

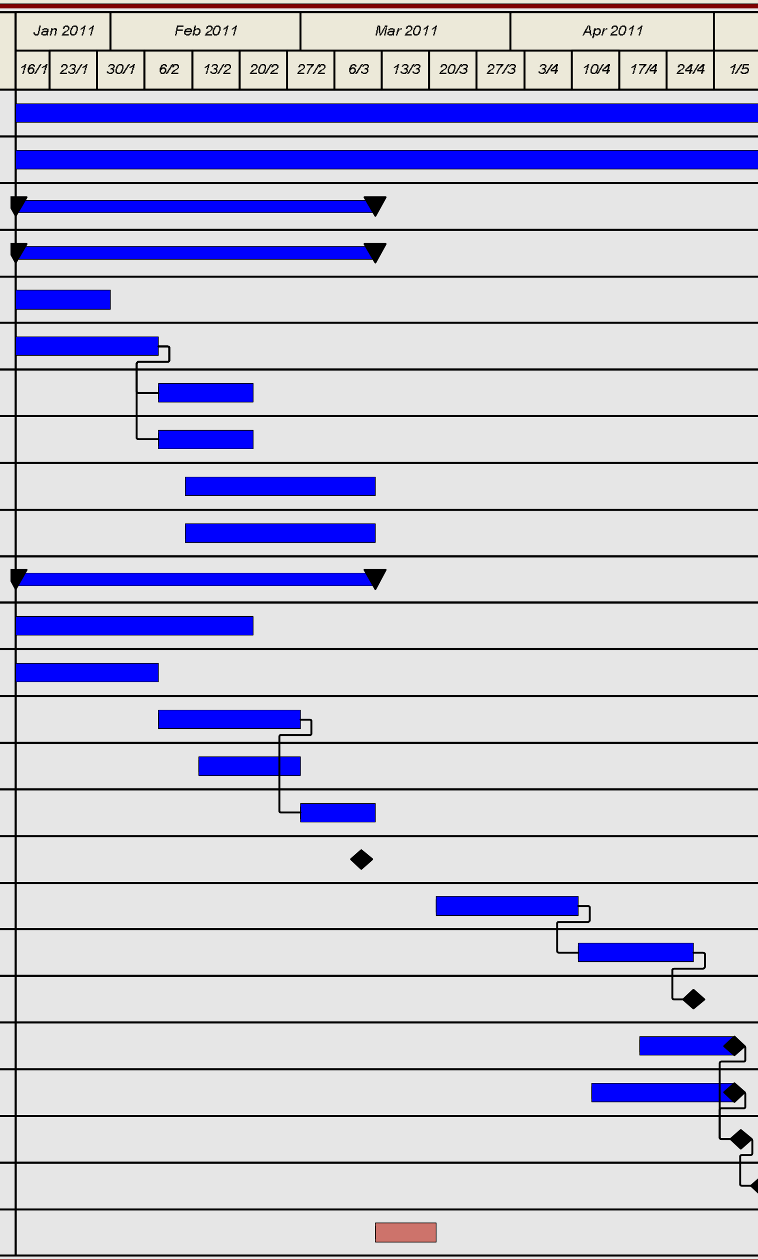
Gantt Chart: Fall 2010

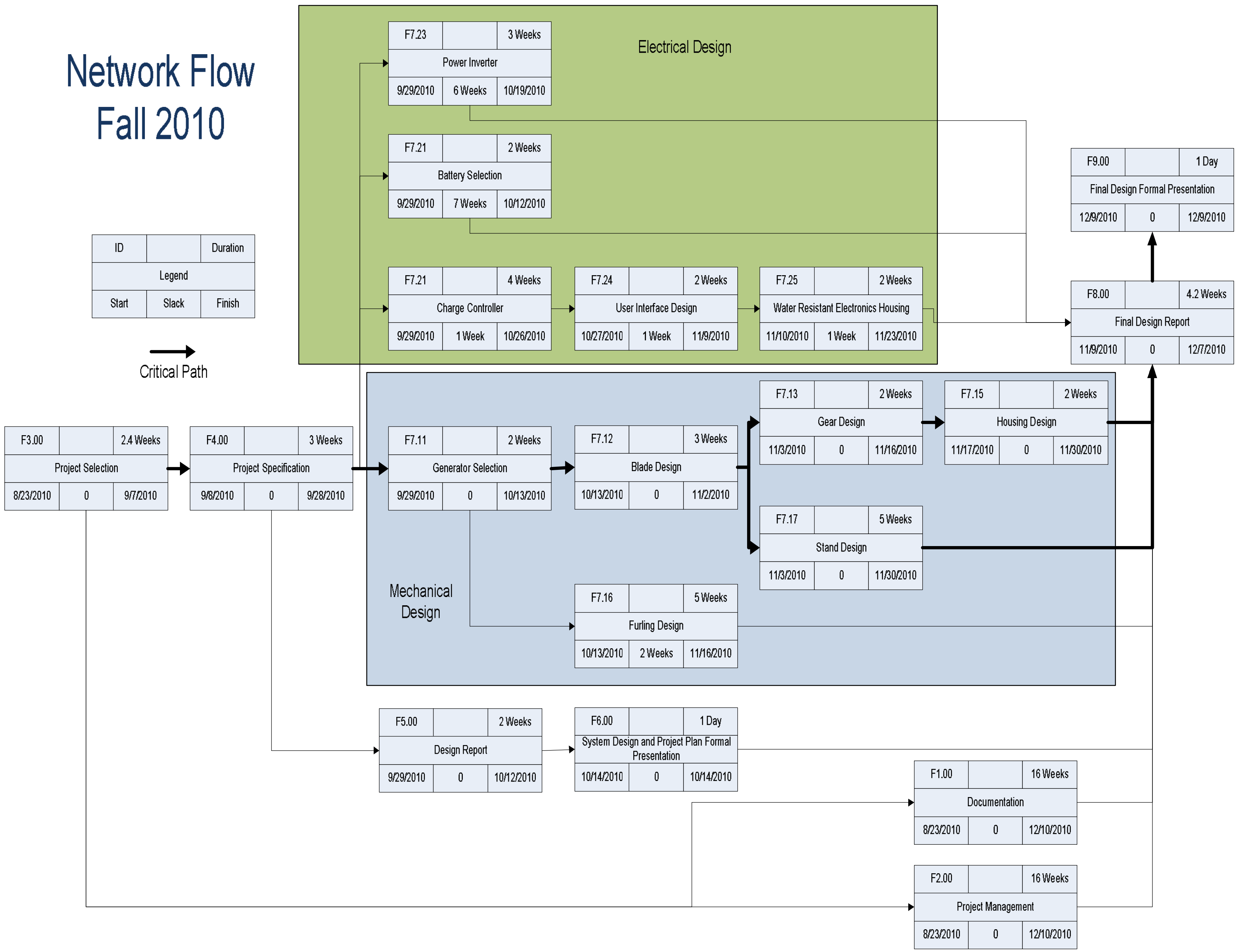
ID	Task Name	Start	Finish	Duration
F1.00	Project Management	8/23/2010	12/10/2010	16w
F2.00	Documentation	8/23/2010	12/10/2010	16w
F3.00	Project Selection	8/23/2010	9/7/2010	2.4w
F4.00	Project Specification	9/8/2010	9/28/2010	3w
F5.00	System Design Report	9/29/2010	10/12/2010	2w
F6.00	System Design and Project Plan Formal Presentation	10/14/2010	10/14/2010	0w
F7.00	**Component Design**	**9/29/2010**	**12/7/2010**	**10w**
F7.10	**Mechanical Design**	**9/29/2010**	**12/7/2010**	**10w**
F7.11	Generator Selection	9/29/2010	10/12/2010	2w
F7.12	Blade Design	10/13/2010	11/2/2010	3w
F7.13	Gear Design	11/3/2010	11/16/2010	2w
F7.14	Housing Design	11/17/2010	12/7/2010	3w
F7.15	Furling Design	10/13/2010	11/16/2010	5w
F7.16	Stand Design	11/3/2010	12/7/2010	5w
F7.20	**Electrical System Design**	**9/29/2010**	**11/23/2010**	**8w**
F7.21	Battery Selection	9/29/2010	10/12/2010	2w
F7.22	Charge Controller	9/29/2010	10/26/2010	4w
F7.23	Power Inverter	9/29/2010	10/19/2010	3w
F7.24	User Interface	10/27/2010	11/9/2010	2w
F7.25	Water Resistant Electronics Housing	11/10/2010	11/23/2010	2w
F8.00	Final Design Report	11/9/2010	12/7/2010	4.2w
F9.00	Final Design Formal Presentation	12/9/2010	12/9/2010	0w
F10.00	Thanksgiving Break	11/19/2010	11/26/2010	1.2w



Gantt Chart: Spring 2011

ID	Task Name	Start	Finish	Duration
S1.00	Project Management	1/18/2011	5/8/2011	15.86w
S2.00	Documentation	1/18/2011	5/8/2011	15.86w
S3.00	**Parts Assembly/Testing**	**1/18/2011**	**3/11/2011**	**7.57w**
S3.10	**Mechanical Systems**	**1/18/2011**	**3/11/2011**	**7.57w**
S3.11	Generator Testing	1/18/2011	1/31/2011	2w
S3.12	Gear and Shaft	1/18/2011	2/7/2011	3w
S3.13	Mechanical Housing	2/8/2011	2/21/2011	2w
S3.14	Blade Mounting	2/8/2011	2/21/2011	2w
S3.15	Furling	2/12/2011	3/11/2011	4w
S3.16	Stand	2/12/2011	3/11/2011	4w
S3.20	**Electrical Systems**	**1/18/2011**	**3/11/2011**	**7.57w**
S3.21	Charge Controller	1/18/2011	2/21/2011	5w
S3.22	Power Inverter	1/18/2011	2/7/2011	3w
S3.23	User Interface	2/8/2011	2/28/2011	3w
S3.24	Battery Testing	2/14/2011	2/28/2011	2.14w
S3.25	Encasement	3/1/2011	3/11/2011	1.57w
S4.00	Project Status Formal Presentation	3/10/2011	3/10/2011	0w
S5.00	System Integration	3/21/2011	4/10/2011	3w
S6.00	System Testing and Modification	4/11/2011	4/27/2011	2.43w
S7.00	Acceptance Tests Complete	4/28/2011	4/28/2011	0w
S8.00	User's Manual	4/20/2011	5/3/2011	2w
S9.00	Final Report	4/13/2011	5/3/2011	3w
S10.00	Final Project Formal Presentation	5/5/2011	5/5/2011	0w
24	Engineering Showcase	5/8/2011	5/8/2011	0w
25	Spring Break	3/12/2011	3/20/2011	1.29w




Network Flow
Fall 2010
ID
Duration
Legend
Start
Slack
Finish
Critical Path
Electrical Design
F7.23
3 Weeks
Power Inverter
9/29/2010
6 Weeks
10/19/2010
F7.21
2 Weeks
Battery Selection
9/29/2010
7 Weeks
10/12/2010
F7.21
4 Weeks
Charge Controller
9/29/2010
1 Week
10/26/2010
F7.24
2 Weeks
User Interface Design
10/27/2010
1 Week
11/9/2010
F7.25
2 Weeks
Water Resistant Electronics Housing
11/10/2010
1 Week
11/23/2010
F9.00
1 Day
Final Design Formal Presentation
12/9/2010
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12/9/2010
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11/9/2010
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Project Selection
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9/7/2010
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3 Weeks
Project Specification
9/8/2010
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9/28/2010
Mechanical Design
F7.11
2 Weeks
Generator Selection
9/29/2010
0
10/13/2010
F7.12
3 Weeks
Blade Design
10/13/2010
0
11/2/2010
F7.13
2 Weeks
Gear Design
11/3/2010
0
11/16/2010
F7.15
2 Weeks
Housing Design
11/17/2010
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11/30/2010
F7.17
5 Weeks
Stand Design
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5 Weeks
Furling Design
10/13/2010
2 Weeks
11/16/2010
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2 Weeks
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Project Management
8/23/2010
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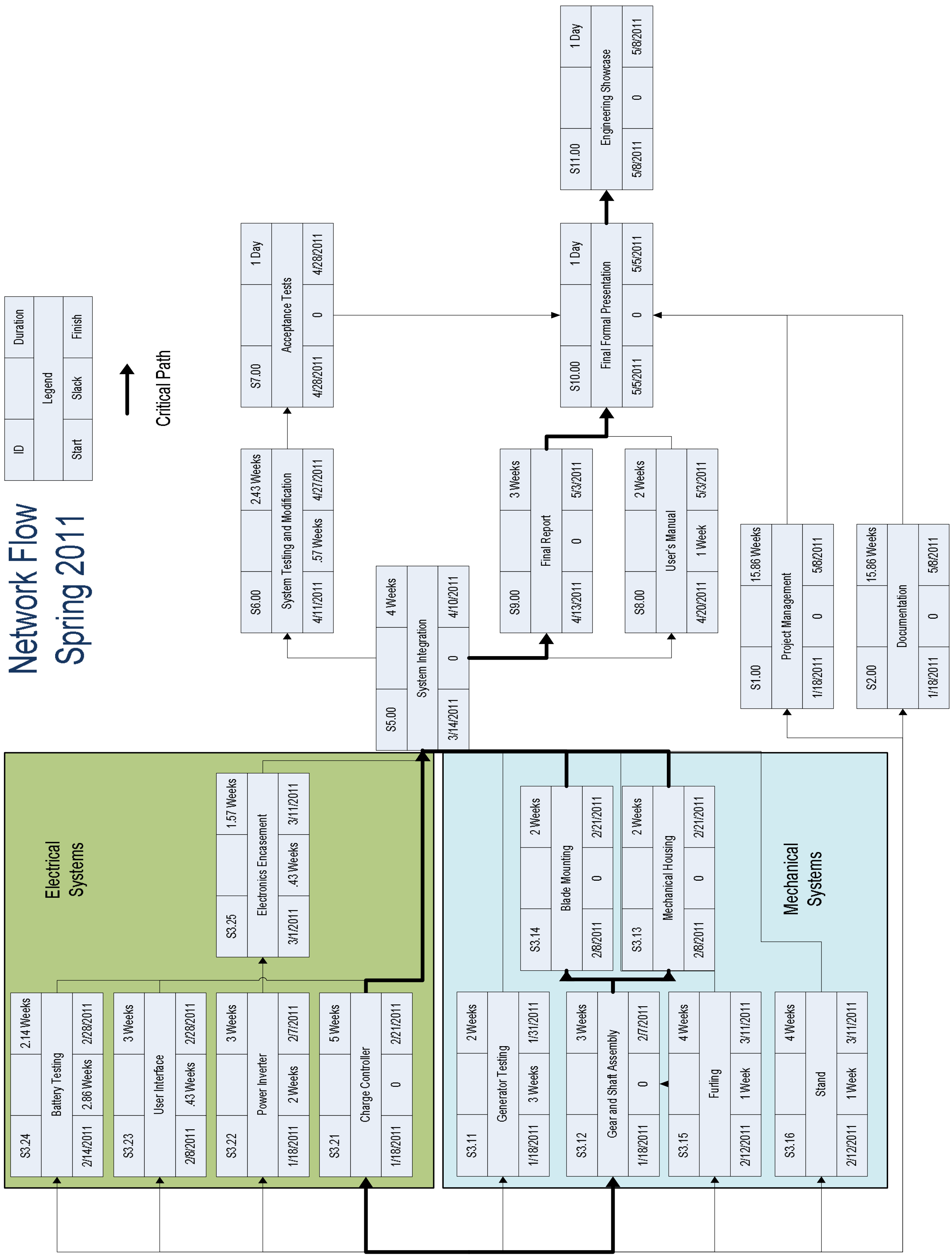
12/10/2010



Network Flow
Spring 2011
ID
Duration
Legend
Start
Slack
Finish
Critical Path
Electrical Systems
S3.24
2.14 Weeks
Battery Testing
2/14/2011
2.86 Weeks
2/28/2011
S3.23
3 Weeks
User Interface
2/8/2011
.43 Weeks
2/28/2011
S3.22
3 Weeks
Power Inverter
1/18/2011
2 Weeks
2/7/2011
S3.21
5 Weeks
Charge Controller
1/18/2011
0
2/21/2011
S3.25
1.57 Weeks
Electronics Encasement
3/1/2011
.43 Weeks
3/11/2011
Mechanical Systems
S3.11
2 Weeks
Generator Testing
1/18/2011
3 Weeks
1/31/2011
S3.12
3 Weeks
Gear and Shaft Assembly
1/18/2011
0
2/7/2011
S3.15
4 Weeks
Furling
2/12/2011
1 Week
3/11/2011
S3.16
4 Weeks
Stand
2/12/2011
1 Week
3/11/2011
S3.14
2 Weeks
Blade Mounting
2/8/2011
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2/21/2011
S3.13
2 Weeks
Mechanical Housing
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System Integration
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1 Day
Engineering Showcase
5/8/2011
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5/8/2011
S1.00
15.86 Weeks
Project Management
1/18/2011
0
5/8/2011
S2.00
15.86 Weeks
Documentation
1/18/2011
0
5/8/2011

Appendix: Requirements Specification

Backpackable Easily-Assembled, Sustainable Turbine
(BEAST)

Requirements Specification
Sean Smith, Josh Gibb, Moses Rotich, Yixiao Zhang

Overview:

Many of us are dependent upon our small electronics ranging from cell phones to laptops for functions varying from information gathering to long distance communication. Unfortunately all of these devices are dependent upon electricity in the form of rechargeable batteries which only last for a set period of usage time and then depend on a steady source of electricity for recharging. On extended stays in areas which do not offer an electricity source, an environmentally-friendly, sustainable, and easily implemented power source is needed. The BEAST will be a solution to that problem intended specifically for long-term trips into remote areas and visits to developing nations where a base camp is required. Military applications and disaster relief efforts are also key markets. The device will consist of a wind turbine that can fit within or on a hiker's backpack at a reasonable weight, be easily assembled in the field with little technical prowess, and supply enough power to efficiently charge cell phone and laptop batteries.

The Deliverables

1. Working wind turbine
2. System Specifications
    1. Code and electric schematics/MULTISIM
    2. CAD drawing
3 Testing report
4. Users' manual
5. Final Report

Principles of Operation

The user will assemble the turbine onto a tripod and securely fasten it to the surroundings. The blades of the windmill will capture energy from available wind and use it to turn an electric generator. An energy storage device will capture the generated electricity, allowing the captured energy to be used at the convenience of the user. A standard United States (NEMA type B) AC outlet (the type typically used in household applications) will be attached to the

energy storage device. The charge amount and generation rate will be displayed to the user. The user can then choose to detach the energy storage device from the turbine and use it off-site or charge their device while the storage device is still attached to the turbine.

Input: The input will be whatever wind energy is available. The system will start generating given at least a 4 m/s breeze and be able to handle wind gusts up to 20 m/s and then stop generation in order to protect the internals of the device.

Output: The turbine will be rated to produce at least 15 W given a 6 m/s wind speed at sea level. The energy storage device will contain at least 200 Wh of energy (enough to charge about three typical laptops) and an inverter will be used to supply 125 VAC 60Hz through a NEMA Type B outlet.

Technical Requirements

1. **Power Generation:** The generator should produce at least 15 W given a 6 m/s wind (typical ground level wind speed) and 130 W at 12 m/s (the typical wind speed used to rate wind turbines).
2. **Power Storage:** At least 200 Wh will be stored in a durable and safe energy storage device. This will provide enough energy to charge three typical 6-cell laptop batteries. The storage device will be detachable and portable for use away from the turbine.
3. **Electrical Safety:** When the storage device is full, electricity will cease being supplied to the storage device. All wires and circuitry will be able to handle the maximum amount of current produced by the turbine.
4. **Mechanical Safety:** The mechanical parts will be stable and able to withstand the high shear and bending stresses placed upon them. A housing will cover the gearing and the turbine in order to protect the user. The lowest point at which the blades spin will be at least 2.14 meters off of the ground.
5. **Portability:** The turbine and all of its components should fit within a large backpacking backpack (85 + liter) and weigh less than 23 kg. It should be easily assembled within an hour after one practice trial by two individuals who have read the user manual using only basic tools (screwdriver, wrench, etc.).
6. **Durability:** The system will be able to withstand frequent assembly and dis-assembly and still be operational. The electrical components will be contained in a water-resistant housing.
7. **User Interface:** The rate at which the energy is being produced and the amount of charge available (empty to full) in the energy storage device will be indicated. A 125 VAC 60Hz NEMA Type B outlet will connect devices to the storage device.

Testing Plan:

1. The wind tunnel in the Ulrey will be used to supply a 6 m/s, 12 m/s, and 20 m/s wind speed to the turbine. The current and voltage going into the battery will be measured at each of those speeds.

2. The battery will be fully charged and then drained with a run-time test.

3. The wind speed will be increased to 20 m/s to check for mechanical stability of the blades and hub. A force that simulates the maximum force applied under peak operating conditions will be manually applied at the hub while the stand is fully assembled and anchored, in order to check for the stability of the stand.

4. The entire device will be weighed, disassembled, and placed in a backpack. Three separate groups of two volunteers will assemble the device with any necessary tools supplied. The average of the completion times of the second attempts must be one hour or less.

5. The device will be assembled and dis-assembled several times to check for durability. The water resistant electronics housing will be tested while empty by measuring the relative humidity inside, then spraying it with water, and then measuring the relative humidity again. If the relative humidity increases by less than 20% relative humidity it passes the test.

6. The indicators will be tested before final installation by measuring known values using them. A multimeter will be used to verify the outlet's output while a laptop and a cell phone are being charged individually.